Higher Education and Firms: on the interaction between research and regional policies

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Abstract

The European national governments have delegated a series of competencies to a central agency called the European Commission. Among them, two are considered in this paper: research policy and regional development. However, delegating those competencies to a central agency does not prevent the national governments to still be active in those fields. Here, we model and discuss how the level of commitment of a central authority toward poor regions affects the design of the best decision process. We explore cases of full centralization and full decentralization, and situations where the two levels of government are allowed to take decisions, either simultaneously or sequentially. In that latter case we make a distinction between a situation where the central agency decides first like in most federations, and a situation where it decides second, then being an agent of the national governments, a setting especially relevant for the European Union. We show in particular that, when the degree of commitment of the centre is high, assignment of redistributive competencies to both levels of power is a better proxy for centralization than decentralization. Additionally, the poorer region may find its best interest in an institutional design where regions decide first.

JEL: H41, H77, I20

Keywords: Higher education, research, interjurisdictional competition, fiscal federalism, public infrastructure.

1 Introduction

The European national governments have delegated a series of competencies to a central agency called the European Commission. Among them, two are considered in this paper: research policy and regional development. However, delegating those competencies to a central agency does not prevent the national governments to still be active in those fields. Here, we model and discuss how the level of commitment of a central authority toward poor regions affects the design of the best decision process. We explore cases of full centralization and full decentralization, and situations where the two levels of government are allowed to take decisions, either simultaneously or sequentially. In that latter case we make a distinction between a situation where the central agency decides first like in most federations, and a situation where it decides second, then being an agent of the national governments, a setting especially relevant for the European Union (EU). We show in particular that, when the degree of commitment of the centre is high, assignment of redistributive competencies to both levels of power is a better proxy for centralization than decentralization. Additionally, the poorer region may find its best interest in an institutional design where regions decide first. Beyond the specificities of the European system, we hope to contribute to a larger debate on the use of policy instruments and the institutional design and assignment of competencies within a federation. Our model assumes two regions, one being initially poorer, and a central agency. Subsidies to researchers affect their distribution between the regions, which in turn affects that of human capital, the relative attractiveness of regions for investment and local social welfare.

The main lesson from the exercise is that the level of commitment of the central authority or agency - i.e. the European Commission - towards the poor regions matters.

In particular, we start confirming that when a central agency has such a commitment to poor regions, a fully centralized redistributive policy is always optimal. However, when that exclusive assignment of redistribution policy to the centre is not feasible, which is typical in a bottom up institution like the EU, the best assignment rule will depend on the degree of commitment of the centre to the welfare of the poor regions. We find that when that degree of commitment is high, an action of both the central agency and the regions may be preferred to a complete decentralization to the regions. In the same way, when the degree of commitment towards a poor region is high a sequential decision process where the central government decides first might be preferred to a sequential process where the regions decide first.

When we further compare the outcome of the simultaneous and sequential decision processes, assuming a high degree of commitment of the centre toward the poor region, we observe that, when the regions are first movers, the poorer region government reduces its subsidy, compared to the other two settings, transferring to the centre the task of attracting researchers in its territory; that behavior generates a gain for the poorer region in terms of researchers and investment, which is larger than when the centre plays first, but smaller however than under simultaneous move by the two levels of authority, and of course than under full centralization. However the cost per researcher located in the poorer region is especially high under simultaneous move. That suggests that the best interest of the poor regions, among th devices where the two levels of power are permitted to play, could be an institutional design where the redistributive commitment of the centre is high and the regions are first movers, an observation which highlights the debate as to the institutional organization of the European Union where Member States are heterogeneous both in degree of development and in ability-to-pay.

1.1 Context and motivation

The EU clearly has the ambition to become one of the most research oriented area in the world - that goal is part of the so-called Lisbon Agenda and it is stressed by the authors of the Sapir Report (Sapir *et al.*, 2003) who recommend "to increase government and EU spending in research and post-graduate education, to allocate research grants according to the highest scientific standards, to create an independent European Agency for Science and Research, and to encourage private-sector R&D via tax credits." The creation of the European Research Council, in short ERC, obeys that program; ERC intends to provide bright scholars from all around the world, with portable EU funded grants.

Throughout this paper we have those researchers in mind and we consider that they have various degrees of mobility across jurisdictions, e.g. in line with the cost of moving laboratories. Each region tries to attract them in its publicly funded university, convinced that better research induces better higher education and improves human capital. In turn, that better human capital should contribute to attract mobile firms and eventually to improve local welfare. In that context one can easily imagine that the central agency - i.e. the EU Commission - decides on a budgetary effort to attract researchers on the territory of the Union and then that national or regional authorities engage into horizontal competition to have those researchers located on their own territory. However, research activity may produce externalities. Let us mention expertise or applied research for firms in the region next door on the one hand, and teaching spillovers on the other hand, the latter taking place only when there is student mobility.[1] Both types of horizontal externality

[1] At that level two specific EU features are at work. On the one hand, universities are prohibited to charge differentiated tuition fees based on the origin of the students, provided they are citizens of the EU. On the other hand, the mobility of graduates is still limited by cultural and linguistic barriers and country attachment as well (Mansoorian and Myers, 1993), so that we may suppose that students return home after completing

are captured in the paper.

A particular feature of the paper is that public subsidies are not directly granted to firms, since most such subsidies are prohibited by the EU law. Instead they are granted to researchers, whose activity is deemed to improve local human capital, and thus attractiveness for investment and eventually the size of local employment and labor income.

Although the role of the ERC, as part of the EU central agency, is limited to developing research in Europe without concern for its distribution among regions, the EU Commission is also in charge of improving the welfare, and primarily employment, in the relatively poorer regions of the EU territory. That redistributive role of the EU central agency is well documented in the literature: Structural and Cohesion Funds are allocated to relatively poor regions and can be used to increase the quality of human capital (Köthenbürger, 2002; Riou, 2006). At a national level a similar pattern is at work and part of the resources allocated by regional authorities may eventually come from European funds. It turns out that various institutions across Europe, such as universities, may receive public funds from various levels of government.[2]

That context explains the focus of the paper on the interactions between research and regional policies, and therefore the characteristics of the modeling strategy adopted: firstly, an effort to attract researchers in Europe is deemed to have been conducted by the central agency without any interregional redistributive concern; secondly, each region tries to have the researchers coming in the university located in its own territory; and, thirdly, the central agency helps the relatively poorer region. Consequently both horizontal and vertical interactions are at work.

1.2 Related literature

Interjurisdictional competition is among the most frequently addressed topics in economic research. It is of interest to scholars active in public economics as well as in economic geography. The most popular way to cope with this issue is to develop models where two local or regional jurisdictions compete in a horizontal game, and where the tax rate levied on the local profits of a mobile firm is the instrument that local authorities use to attract the firm - see the survey proposed by Wilson (1999). However, though the role of the tax instrument is far to be negligible - see e.g. Benassy-Quéré *et al.* (2005), Devereux-Griffith (2003) - other studies propose models where the instrument is the quantity of a specific public input such as public infrastructures - see, for example, Keen and Marchand (1997) and, more re-

their training abroad.

[2] As an example 55 per cent of the resources from the University of Saint-Etienne in France come from the French national government, 36 per cent come from the Region and 9 per cent from more local authorities (Ahues, 2005).

cently, Dembour and Wauthy (2004), Justman, Thisse and van Ypersele (2005) and Wilson (2005).

On the other hand, a large and increasing volume of literature focuses on education and human capital formation, including models of interuniversity competition (e.g. del Rey, 2001) from where we know that the quality of human capital may be a decisive factor when a firm has to take a location decision, and is of primary importance for regional development.

This paper is also inspired by Bordignon, Manasse and Tabellini (2001) study of the optimal redistributive policy between regions when both regional and central authorities overlap.

Our research is close to the topic investigated by Besley and Coate (2002) which studies how should the public good be allocated and the costs of its provision be shared, either in a centralized system, in which spending decisions are made by a central government and financed from general revenues, or in a decentralized system, in which choices are made by local governments and financed by local taxation. In this paper, the central agency also deliberately discriminates between the regions by adopting a preference for the poorer when allocating regional development funds; therefore centralization does not imply uniformity and we move apart from Oates (1972) traditional approach.

In our context, characterized by redistributive purposes, centralization appears, in principle, to be the most efficient setting, although European institutional design prevents its sole operation. As Keen (1998) notes, in the context of his contribution, "the federal government may simply (...) be restricted in the direction or extent of the vertical transfers between levels of government"; this is clearly the case in the situations addressed by this paper.

Though developed in another context, especially relevant for European taxation, Janeba and Smart (2003) also questions our analysis. Indeed, why to model public authorities acting through subsidies to a mobile base like our researchers, rather than through direct subsidies to a mobile firm or to the provider of another input? A justification of our approach is that European regulation mostly prohibits state aid to firms.[3]

[3] As Collie (2000) mentions, article 92(1) of the EU treaty states that “any aid granted by a member state or through state resources in any form whatsoever which distorts or threatens to distort competition by favoring certain undertakings or the production of certain goods shall, in so far as it affects trade between member states, be incompatible with the common market”. However, he adds, although this statement seems unambiguous, it does not amount to an absolute prohibition of state aid since there are a number of exceptions to this general rule, including – see article 92 (3a) – “aid to promote the economic development of areas where the standard of living is abnormally low or where there is serious underemployment”.

1.3 Organization of the paper

Our willingness to be as close as possible to the European institutional features also commands the organization of the paper. After a presentation of the players of the model and of their respective objectives (Section 2), we investigate the interactions between them, within the framework of a simple game with complete information (Section 3). In Section 3, we first focus on centralization versus decentralization, the first of those polar cases providing a benchmark, by which we mean that other decision-making processes may not be optimal in the sense that they may not replicate what would be chosen in a unitary state setting or centralized framework with the same pattern of preferences (Boadway, 2004); then we examine the situation where the two levels of authorities act simultaneously. Thereafter (Section 4), we address situations falling within a sequential game; then either the centre moves first or it moves second. When moving first, the centre determines the framework and regions adapt to the policy pursued by the central agency; that seems in line with usual practice in federations (Boadway, 2004). However within the EU, the central agency, to some extent, applies policies which have been decided by the national governments at the occasion of EU Council meetings.[4] Therefore, exploring what happens when the central agency moves second, being an agent of the regions, makes sense.[5] A comparison of the situations for the specific case of a Rawlsian central agency is conducted in Section 5. Section 6 proposes policy-oriented conclusions and directions for further research.

2 The Players of the Model

The players of the model are (i) the firm - deemed to be mobile across two jurisdictions, it maximizes its value considering the quality of human capital across jurisdictions, and takes decision as to the distribution of its location at step 3 of the game; (ii) the researchers who receive grants from the central agency - also deemed to be mobile across jurisdictions, they decide at step 2 on where to locate, based on the extra subsidies they receive from the various authorities; (iii) the two regional governments and the central agency - at step 1, they provide the researchers with public funds, in order to maximize their social welfare, with the central agency influenced by some interjurisdictional distributive concerns. Figure 1 presents the order of play.

[4] The EU Council is the meeting of the heads of states and governments of the EU member states; one of the members of the Council, changed every six months, serves as president of the Union.

[5] As Boadway (2004) notes "changing the order of movement - or the ability of policy-makers to commit - can have a serious effect on equilibrium outcomes"; that situation might be related to the soft budget constraint literature - see Wildasin (1997), Boadway, Cuff and Marchand (2003).

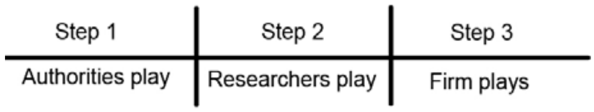

Figure 1 - Order of Play

In Step 1 we examine various scenarios: only the central agency moves (a case referred with superscript C and called $C-$setting), only the two regional governments move simultaneously (D), the three public authorities move simultaneously (S), the central agency plays first and the regions play second (L) and conversely the regions play first and the central agency play second (R) - see Table 1.

Table 1 - Alternative settings for Step 1		
C	Centralization	*Only Centre moves*
D	Decentralization	*Only regions move*
S	Simultaneous game	*Centre and regions move*
L	Sequential game	*Centre moves first*
R	Sequential game	*Regions move first*

2.1 The Firm

The firm takes decision in the 3rd step.

Suppose a firm deemed to be mobile across jurisdictions. It decides on the distribution of a given investment, standardized to unity, between two jurisdictions i and j, in order to maximize its value. The fraction invested in i is denoted by α and that invested in j by $1-\alpha$. Initially - to compare with the EU integration process imagine it is before the free circulation of investment being permitted - the values of those parameters are respectively equal to α_0 and $1-\alpha_0$. Departing from these values has a cost represented by the quadratic function $(\gamma/2)(\alpha-\alpha_0)^2$. This cost can be regarded as that of dismantling, transporting and rebuilding a plant, firing and hiring labor force and pushing up the wage rate in the hosting region. The production in either jurisdiction depends on the firm's local investment and on the skill of the human capital available in the jurisdiction, x_h, $h=i,j$. Thus the firm maximizes

$$V = \alpha x_i + (1-\alpha)\, x_j - (\gamma/2)(\alpha-\alpha_0)^2 \tag{1}$$

The first order condition of that maximization gives the firm's equilibrium distribution of investment, as

$$\alpha = \alpha_0 + \frac{x_i - x_j}{\gamma} \tag{2}$$

We verify that the second derivative of (1) w.r.t. α is negative.[6]

2.2 The Researchers

The researchers take decision in 2d step.

Suppose that the central agency, through the European Research Council, has attracted bright researchers from all around the world, providing them with an equal grant, per researcher; let the number of such researchers be normalized to unity. For exogenous reasons, a fraction m_0 from those researchers has initially decided to locate in the university of region i and a fraction $1 - m_0$ to locate in that of region j.

As illustrated by Figure 2, let us assume that the researchers are identically distributed on a segment of length 1; researchers left of point m_0 are initially affiliated with the university of i and researchers located right of that point with the university of j. Moreover, the distance between the actual location of a researcher on the segment, and point m_0, measures the cost for him to move to the other region's university. Therefore, the cost of moving from j to i, for a researcher located at point m right of m_0, is $\mu(m - m_0)$. Then, if he receives the promise of a subsidy F_i if he goes to i and of a subsidy F_j if he stays in j, he will decide to move if $F_i > F_j + \mu(m - m_0)$. It turns out that for the marginal researcher, the one indifferent between remaining in j and moving to i, is such that

$$F_i = F_j + \mu(m - m_0)$$

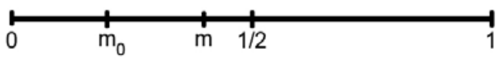

Figure 2 - Distribution of the researchers between the regions

[6] The way we have modeled the firm deserves some comments. Indeed that modeling strategy seems to neglect the possibility of increasing returns related to the local accumulation of skilled workers and knowledge. That possibility might be captured by substituting x_h^2 for x_h in equation (1). Then the first order condition of the maximization of the value of the firm becomes

$$\alpha = \alpha_0 + \frac{x_i - x_j}{\gamma}(x_i + x_j) = \alpha_0 + \frac{x_i - x_j}{\gamma/\tilde{x}}$$

with $\tilde{x} = x_i + x_j$. Consequently the equilibrium value is larger (smaller) than under equation (2) when x_i is larger (smaller) than x_j. In the sequel of the paper cost parameter γ may be reinterpreted as $\gamma/\tilde{x}$ in order to capture such increasing returns phenomenon.

As a consequence, the number of researchers deciding to locate in the university of region i will be

$$m = m_0 + \frac{F_i - F_j}{\mu} \tag{3}$$

2.3 The Human Capital

The quality of human capital in region i, x_i depends on a initial value $\underline{x}_i$ and on the activity of the researchers, also called the academic community. In particular, the relationship between the local human capital and the academic community's activities is given by the equation

$$x_i = \underline{x}_i + \varphi m + \varphi\delta (1 - m) \tag{4}$$

This equation implies that the skill of the workers in region i increases with the activity of the academic community in that region and, if $0 < \delta \leq 1$, also with the activity of the academic community in the other region so that spillover effects may be at work. Moreover, whatever the level of activity of the academic community, the initial level of human capital in each region matters, what is actually in line with empirical observation; the parameter φ reflects the effect of the extra university activity on the level of human capital, thus the efficiency in the transmission of knowledge from the University to the population.[7]

Using equations (4) and (3), equation (2) becomes

$$\alpha = \lambda_i + \frac{2\varphi (1 - \delta)}{\gamma} \frac{F_i - F_j}{\mu} \tag{5}$$

so that the distribution of the activity of the firm in the absence of public incentives ($F_i = F_j = 0$) is

$$\lambda_i = \alpha_0 + \frac{\underline{x}_i - \underline{x}_j}{\gamma} - \varphi \frac{1 - \delta}{\gamma} (1 - 2m_0) \tag{6}$$

where α_0 is the initial distribution of investment, $\underline{x}_i$ and $\underline{x}_j$ the initial levels of human capital, δ the indicator of possible spillover effect, and m_0 the initial distribution of academic community activities. Obviously, if spillover is complete, $\delta = 1$, by which is meant that the academic community affects the two regions similarly wherever it locates, there is no reason to spend money to change the distribution of researchers across territories.

Parameter λ_i summarizes the initial characteristics of the regions, so that region i can be regarded as poorer than region j if $\lambda_i < \lambda_j$; moreover λ_i will be more likely to be smaller than λ_j, the less endowed is region i in physical capital α_0, in human capital $\underline{x}_i$ and in initial presence of the academic community m_0.

[7] Notice that the new total amount of human capital is $\tilde{x} = x_i + x_j = \underline{x}_i + \underline{x}_j + \varphi (1 + \delta)$.

Therefore, in the sequel of the paper, and without loss of generality, we assume that region i is initially the poorer region, by which we mean that $\underline{x}_i < \underline{x}_j$ and $\alpha_0, m_0 < 1/2$, sufficient conditions to have $\lambda_i < \lambda_j$.

In this model students - including adults enrolled in continuous learning programs - are deemed to have a strong attachment to their own region so that there is no migration of labor across regions. Though such an assumption may hurt some readers it is perfectly consistent with empirical observations in Europe where most degree holders are employed in their jurisdiction of origin, even if they have spent some time studying abroad.

Therefore, a non zero value of parameter δ captures the opportunity for residents of one jurisdiction to increase the human capital of their native jurisdiction by studying abroad and returning home after completing their studies. In that sense we can then read δ as an indicator of students (not graduates) mobility. As a consequence, even if no higher education facility locates in, say, region i, the skill level of human capital in that region will increase from $\underline{x}_i$ up to $\underline{x}_i + \varphi\delta$, with $0 \leq \delta < 1$.

Moreover mobility of students is not the only source of spillover permitted by parameter δ. Another interpretation of that parameter is that the affiliate of the firm located in one jurisdiction may benefit from services of the academic community located in the other jurisdiction, like having some tests performed by a laboratory in the other jurisdiction.

2.4 The Authorities

Three public authorities may be active in this model, two regional governments on the one hand, and a central agency on the other hand. All those authorities take decision in the 1st step.

2.4.1 The Regional Governments

Each regional government tries to attract the activity of the academic community in order to increase the human capital in its jurisdiction and thus to attract the mobile firm, which in turn is deemed to create jobs or to improve labor income in the jurisdiction. To this end it fixes the level of the per capita subsidy that it gives to researchers choosing to nest in the local university, t_h, $h = i, j$; that subsidy is assumed to be financed through a lump sum tax levied on the jurisdiction. However transforming a lump sum tax into a transfer to the academic community has a cost; that cost is denoted by u, the shadow price of public funds. Moreover, we denote the shadow price of labor income by w - see Boadway and Bruce (1984) on the shadow prices of public funds and labor income, and Laffont-Tirole (1993) on the former.

We also assume that the central agency will provide a subsidy τ_h to each researcher located in the poorer region. Therefore the total public subsidy per researcher amounts to $F_h = t_h + \tau_h$, with $\tau_h \geq 0$ if region h is the poorer, $\tau_h = 0$ otherwise; and we note $F_i = t_i + \tau_i$ and $F_j = t_j$ since region i is assumed to be initially the poorer region.

In region i, the regional government decides on the optimal subsidy per researcher. That subsidy maximizes the difference between a social benefit, measured by the effect of the human capital driven investment of the firm on the income of the population, $w\alpha$, and the social cost of the subsidies to the researchers locating in the region, umt_i. Thus it maximizes

$$W_i = w\alpha - umt_i \tag{7}$$

with respect to t_i. From the first order condition of this maximization we obtain the reaction function

$$t_i = M_i - \frac{\tau_i}{2} + \frac{t_j}{2} \tag{8}$$

with

$$M_i = \frac{w\varphi\,(1-\delta)}{u\gamma} - \frac{\mu m_0}{2} \tag{9}$$

A similar maximization by the other region government implies

$$t_j = M_j + \frac{\tau_i}{2} + \frac{t_i}{2} \tag{10}$$

with

$$M_j = \frac{w\varphi\,(1-\delta)}{u\gamma} - \frac{\mu\,(1-m_0)}{2} \tag{11}$$

Observe that

$$M_j = M_i - \frac{\mu\,(1-2m_0)}{2} < M_i \tag{12}$$

since $m_0 < 1/2$ by assumption. And notice that

$$\frac{dM_i}{d\delta}, \frac{dM_j}{d\delta} < 0$$

so that the existence of spillover effects from higher education - including some degree of students' mobility - reduces the intercept of the reaction function and thus the level of *per capita* subsidies granted by local governments to scholars choosing for that location. However we constrain M_i and M_j to be positive for any value of $m_0 \in [0, 1/2]$; this implies that

$$\frac{w\varphi\,(1-\delta)}{\mu u\gamma} > \frac{1}{2} \tag{13}$$

These reaction functions are correctly shaped, in the sense that the slopes are smaller than one. Local subsidies are strategic complements, while central subsidies are strategic substitutes. Moreover both M_i and M_j increase with φ so that an increased efficiency in the transmission of knowledge from the universities pushes the intercept of the reaction functions upward.

Again, the second derivative of (7) with respect to t_i is negative.

2.4.2 The central agency

The central agency pursues the best interest of the member regions with possibly a distributive concern. When the central agency has a distributive concern, it transfers a subsidy to every researcher deciding to locate in the initially poorer region, here region i. Therefore researchers locating in poorer region i receive from the central agency a per capita subsidy $\tau_i \geq 0$ while those locating in richer region j receive no subsidy from the centre, $\tau_j = 0$. To determine the amount of those subsidies, the central agency maximizes a Social Welfare Function defined on the social benefits occurred to the regions, $w\alpha$ and $w(1-\alpha)$, with α determined by (5), and on the social cost of the amount of funds transferred to the researchers deciding to locate in i, $um\tau_i$. Using such a Social Welfare Function implies that a distributive concern is a necessary condition for τ_i being positive, but not a sufficient one: the social cost of the subsidy can be too high compared to the benefit, for the subsidy to be decided.

Let us denote by ψ the degree of commitment of the centre toward the poorer region, i. If the centre has no redistributive concern, $\psi = 1/2$. At the other end, for a Rawlsian centre $\psi = 1$. Therefore we assume that $\psi \in [1/2, 1]$ and adopt the following expression for the Social Welfare Function[8]

$$W = w\psi\alpha + w(1-\psi)(1-\alpha) - um\tau_i \tag{14}$$

Then, defining

$$\tilde{\psi} = 2w(1-\psi)\varphi\frac{1-\delta}{u\gamma} \tag{15}$$

so that $\tilde{\psi} = 0$ if $\psi = 1$ and $\tilde{\psi} = w\varphi(1-\delta)/u\gamma$ if $\psi = 1/2$, the maximization of (14) w.r.t. τ_i implies

$$\tau_i = M_i - \tilde{\psi} - \frac{t_i - t_j}{2} \tag{16}$$

and obviously the intercept decreases when the preference of the central agency for the poorer region goes down.

[8] Alternatively we could use an Atkinson-like social welfare function applied to our issue $W = w\frac{\left[\alpha^{1-\varepsilon}+(1-\alpha)^{1-\varepsilon}\right]}{1-\varepsilon} - um\tau_i$.

Then, two particular values of ε may deserve attention: the case where the central agency has no redistributive concern, characterized by $\varepsilon = 0$, and that where it has a Rawlsian redistributive concern, characterized by $\varepsilon \to \infty$. In the former case, $W = w - um\tau_i$ and the maximization of the Social Welfare Function implies $\tau_i = 0$, since the transfer has only a cost. In the latter case, $W = w\alpha - um\tau_i$ since region i is initially the poorer one. Between those extreme values of ε the social welfare function gives a larger weight to the social benefit in the poorer region than in the richer one.

3 Polar cases and simultaneous move of the authorities

In this section, we first investigate and compare two polar cases corresponding respectively to full centralization case C in Table 1, which provides us with a benchmark, and full decentralization, case D. Then we turn to a situation where the various levels of authority move simultaneously, case S. As mentioned, using centralization outcome as a benchmark means that we suppose that other decision-making processes may not be optimal in the sense that they may not replicate what would be chosen in a unitary state setting or centralized framework with the same pattern of preferences.

3.1 Full centralization, a benchmark case

In this case, among the three public authorities, only the central agency moves. Then, from equation (16),

$$\tau_i^C = M_i - \tilde{\psi} \tag{17}$$

Notice that the subsidy is never negative: if $M_i - \tilde{\psi}$ is negative, the subsidy vanishes and the central agency does not intervene.

The effects of the subsidy on the distribution of the academic community and on the location of the firm respectively are

$$\Delta m^C = m^C - m_0 = \frac{1}{\mu}\left(M_i - \tilde{\psi}\right) \tag{18}$$

and

$$\Delta \alpha^C = \alpha^C - \lambda_i = \frac{2\varphi\left(1-\delta\right)}{\gamma}\frac{1}{\mu}\left(M_i - \tilde{\psi}\right) \tag{19}$$

Consequently the welfare gain, compared to a situation without incentives to locate in a particular region, amounts to

$$\Delta W^C = \frac{u}{\mu}\left(M_i - \tilde{\psi}\right)^2 \tag{20}$$

Given the composition of M_i and $\tilde{\psi}$, we observe that the subsidy paid by the central agency, as well as its effect on the attraction of the academic community, on the attraction of the mobile firm, and the social welfare as well, unsurprisingly increases with the importance of the commitment of the centre toward the poorer region, ψ, and with the efficiency in the transmission of knowledge from the University to the population, φ. Conversely the subsidy and its effects decrease with the high of the initial allowance in university staff of the poorer region, m_0, with the importance of the externality, δ, and with the relative immobility of the academic community, μ, and of the firm, γ.

3.2 Full decentralization, an horizontal game

If only the regional governments move, reaction functions (8) and (10) reduce to

$$t_i^D = M_i + \frac{t_j}{2},\ t_j^D = M_j + \frac{t_i}{2}$$

generating the equilibrium values of the regional subsidies

$$t_i^D = \frac{4M_i + 2M_j}{3},\ t_j^D = \frac{4M_j + 2M_i}{3} \tag{21}$$

Since M_i and M_j are positive - see equation (13) above for the condition - per researcher subsidies are also positive.

The impacts on the distribution of the academic community and of the activity of the firm become

$$\Delta m^D = \frac{1}{\mu}\frac{2\left(M_i - M_j\right)}{3} \tag{22}$$

and

$$\Delta\alpha^D = \frac{2\varphi\left(1-\delta\right)}{\gamma}\frac{1}{\mu}\frac{2\left(M_i - M_j\right)}{3} \tag{23}$$

for a total budgetary effort by the two players amounting to $mt_i^D + (1-m)\,t_j^D$.

The overall welfare impact, thus the sum of welfare gains and losses of the three authorities, amounts to

$$\Delta W = \left(2\psi - 1\right) w\Delta\alpha - um\left(t_i + \tau_i - t_j\right) - ut_j \tag{24}$$

which, here, reduces to

$$\begin{aligned} \Delta W^D &= w\left(2\psi-1\right)\Delta\alpha - um\left(t_i - t_j\right) - ut_j \\ &= 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\frac{2}{3}\left(M_i - M_j\right) - \frac{u}{\mu}\left[\frac{2}{3}\left(M_i - M_j\right)\right]^2 \\ &\quad -u\frac{2}{3}\left(M_i + 2M_j\right) \end{aligned} \tag{25}$$

The overall welfare gain will be used in the sequel of the paper in order to compare the various settings examined.

3.3 A first comparison

Based on equations (20) and (25), we can show that the welfare gain is larger under centralization than under decentralization. By that latter statement we mean that decentralization cannot replicate the welfare gain reached under centralization, for any relevant degree of commitment toward the poorer region. Actually, the intervention of the central agency, characterized by $\tau_i^C > 0$, may need a degree of commitment toward the poorer region larger than $\psi = 1/2$. The proposition below summarizes that observation.

Proposition 1 *It exists a threshold value* ψ^C *of* ψ, $\psi^C \geq 1/2$, *such that below that value, when* $\psi \in \left[1/2, \psi^C\right]$, *the central agency does not intervene in a centralized setting,* $\tau_i^C = 0$; *above that value, when* $\psi \in \left[\psi^C, 1\right]$, *the central agency intervenes in a centralized setting and, then, the outcome under centralization is larger than that under decentralization,* $\Delta W^C > \Delta W^D$.
Proof. *see Appendix A.1.* ■

The message of the proposition for sure confirms earlier findings as to the superiority of centralization over decentralization in redistribution matters. Besides that confirmation it sets forth that a certain degree of commitment toward the poorer region is necessary for the centre to intervene and that such threshold value depends on a series of parameters. Indeed

$$\psi^C \equiv \frac{1}{2} + \frac{\mu m_0}{4} \frac{u\gamma}{w\varphi\left(1-\delta\right)} \tag{26}$$

Interestingly, $\psi^C = 1/2$ if there is no academic community initially located in the poorer region, $m_0 = 0$, and then it increases with the value of that parameter. Moreover,

$$\frac{d\psi^C}{d\mu}, \frac{d\psi^C}{d\gamma}, \frac{d\psi^C}{d\delta} > 0$$

which means that the threshold value increases with the immobility of the researchers and of the firm, and with the size of the externality as well: when the cost of the intervention compared with its incentive effect on the researchers and the firm becomes larger, then the central agency is less likely to act, by which is meant that a higher degree of commitment toward the poorer region is required for that authority to intervene. Similarly when the human capital enrichment becomes less dependent of the location of the researchers, then a higher commitment of the central agency toward the poorer region is also requested for that agency to act.

3.4 Simultaneous move of the two levels of authority

Now if the three public authorities move simultaneously, the equilibrium tax rates are determined by the system of three equations (8), (10) and (16). It turns out that

$$t_i^S = \frac{2M_i + M_j + \tilde{\psi}}{2},\ t_j^S = \frac{2M_i + 3M_j - \tilde{\psi}}{2},\ \tau_i^S = \frac{2M_i + M_j - 3\tilde{\psi}}{2} \tag{27}$$

Notice that if τ_i^S is positive, so that the central agency actually intervenes, then t_i^S and t_j^S are positive too.

Consequently,

$$\Delta m^S = \frac{1}{\mu} \frac{2M_i - M_j - \tilde{\psi}}{2} \tag{28}$$

and

$$\Delta \alpha^S = \frac{2\varphi (1-\delta)}{\gamma \mu} \frac{2M_i - M_j - \tilde{\psi}}{2} \tag{29}$$

for a total budgetary cost $m\left(\tau_i^S + t_i^S\right) + (1-m)\, t_j^S$.

The overall welfare effect becomes

$$\begin{aligned} \Delta W^S &= w(2\psi - 1)\Delta\alpha - um(t_i + \tau_i - t_j) - ut_j \\ &= 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\frac{2M_i - M_j - \tilde{\psi}}{2} - \frac{u}{\mu}\left[\frac{2M_i - M_j - \tilde{\psi}}{2}\right]^2 \\ &\quad -u\frac{2M_i + 3M_j - \tilde{\psi}}{2} \end{aligned} \tag{30}$$

We can compare now the simultaneous move game with the two polar situations depicted above. Let us do it in terms of overall welfare gain, of distribution of the academic community and the investment, and of subsidy per researcher.

Regarding welfare gain, the comparison of the corresponding equations (20) and (30) enables to suggest that, again when the central agency intervenes, even as single player, the welfare gain is larger under centralization than under simultaneous move. Therefore,

Proposition 2 *It exists a threshold value ψ^S of ψ, $\psi^S \geq \psi^C \geq 1/2$, such that below that value, when $\psi \in \left[1/2, \psi^S\right]$, the central agency does not intervene in a simultaneous move setting, $\tau_i^S = 0$; above that value, when $\psi \in \left[\psi^S, 1\right]$, the central agency intervenes and, then, the outcome under centralization is larger than that under simultaneous move, $\Delta W^C > \Delta W^S$.*
Proof. *See Appendix A.2* ■

Completing that comparison with that of equations (25) and (30), we find out that a threshold value of the degree of commitment of the central agency toward the poorer region exists such that above that value, the simultaneous move outcome is larger than the decentralization one although the converse is true below that threshold; however, although that threshold value is larger than those observed previously, we have no guarantee that it is not larger than one under the restriction adopted so far on the combined value of the parameters.[9] We can then issue the following proposition,

Proposition 3 *It exists a critical value ψ^{SD} of ψ, larger than ψ^S and ψ^C, such that, for $\psi \geq \psi^{SD}$ the welfare gain in case of centralization is larger than the welfare gain in the case of simultaneous move which in turn is larger than the welfare gain under decentralization, $\Delta W^C > \Delta W^S > \Delta W^D$; and for $\psi \in \left[\psi^S, \psi^{SD}\right]$, the welfare gain in case of centralization is larger than*

[9] Especially the restriction that $\frac{w\phi(1-\delta)}{\mu u \gamma} > \frac{1}{2}$

the welfare gain in the case of decentralization which in turn is larger than the welfare gain under simultaneous move, $\Delta W^C > \Delta W^D > \Delta W^S$.
Proof. *See Appendix A.3* ■

That proposition suggests a policy lesson. Indeed, although there is no doubt on the superiority of the centralization design in the present problem, when such solution is not feasible[10] the overlapping of competencies allowing both levels of authority to intervene might be better than the sole action of regional governments. Especially this will be the case in a union of countries or regions sufficiently advanced for allowing a relatively strong commitment of the central institution toward the poorer region. However, if the level of commitment of the centre towards the poorer region is low, a complete decentralization of policies should be preferred.

Table 2 below summarizes the three propositions issued so far.

Table 2 -Ranking of institutional devices				
ψ	$\psi < \psi^C$	$\in [\psi^C, \psi^S]$	$\in [\psi^S, \psi^{SD}]$	$\psi > \psi^{SD}$
τ	$\tau_i^C, \tau_i^S = 0$	$\tau_i^C > 0, \tau_i^S = 0$	$\tau_i^C, \tau_i^S > 0$	$\tau_i^C, \tau_i^S > 0$
ΔW		$\Delta W^C > \Delta W^D$	$\Delta W^C > \Delta W^D$ $> \Delta W^S$	$\Delta W^C > \Delta W^S$ $> \Delta W^D$

To complete the comparison conducted so far let us examine whether not being at the benchmark - the centralization case - implies too many or too few researchers in the initially poorer region, and consequently involves too much or too little investment by the firm. We can find out threshold values of the commitment parameter which allow us to rank the changes involved by the different settings investigated, in terms of number of researchers and of investment, thus in terms of sole benefits. In other words,

Proposition 4 *There exist threshold values* ψ_m^{SD}, ψ_m^{CD} *and* ψ_m^{CS} *of* ψ, *with* $\psi^C \leq \psi_m^{SD} \leq \psi_m^{CD} \leq \psi_m^{CS} \leq \psi^{SD}$ *such that the ranking provided by Table 3 appears, between* Δm^C, Δm^S *and* Δm^D, *and similarly between* $\Delta\alpha^C$, $\Delta\alpha^S$ *and* $\Delta\alpha^D$
Proof. *See Appendix A.4* ■

Table 3 -Ranking of changes in m and α				
ψ	$\psi < \psi_m^{SD}$	$\in [\psi_m^{SD}, \psi_m^{CD}]$	$\in [\psi_m^{CD}, \psi_m^{CS}]$	$\psi > \psi_m^{CS}$
Δm	$\Delta m^D > \Delta m^S$ $> \Delta m^C$	$\Delta m^S > \Delta m^D$ $> \Delta m^C$	$\Delta m^S > \Delta m^C$ $> \Delta m^D$	$\Delta m^C > \Delta m^S$ $> \Delta m^D$

Note: $\Delta\alpha$ is a linear function of Δm

[10] Remember the statement of Keen (1998) quoted in the introduction and more generally the EU institutional context.

And if the degree of commitment to the poorer region is relatively large, Δm^S is closer to Δm^C than Δm^D; and similarly for $\Delta\alpha$. That confirms the conclusion suggested from Proposition 3 above.

In terms of subsidies, we can observe that under decentralization - see equation (21) -, the subsidy per researcher granted by the poorer region is larger than the one proposed by its rival so that the poorer region is clearly more aggressive than the richer one, a result similar to what we observe in models of tax competition between asymmetric countries.

On the other hand, if the central agency comes into the game - see equation (27) - its subsidy acts as a substitute for the budgetary effort of the poorer region. Then, the *per capita* of researcher amount of money allowed by the poorer region goes down when the commitment of the centre increases. This is clearly the case when $\psi = 1$ or $\tilde{\psi} = 0$; in that latter situation, the subsidy granted by the poorer region is equal to that provided by the centre, and their sum is larger than the amount granted by the richer region. That sum is also larger than the subsidy granted by the sole poorer region in the decentralized setting; consequently the response of the richer region is also larger and simultaneous move is potentially more costly than decentralization, and *a fortiori* than centralization - see also Section 5 for that case.

From a policy point of view, when reserving to the sole centre the competencies aiming at redistributing research activity between the regions is not feasible, in a sufficiently advanced union of countries or regions, allowing the competencies in that matter to both levels of power may be a better choice in terms of social welfare and in terms of redistribution of the researchers than to reserve them to the sole regions. However that option may turn to be more costly than the other two.

4 Sequential game

So far, either only the central agency acts or the various authorities play simultaneously. That last device has revealed to be an interesting proxy for centralization when the degree of commitment of the centre toward the poorer region is high; however it may be costly. Let us now investigate what happens if the two levels of power no longer act simultaneously but sequentially. Two cases deserve interest. In the first one, the centre plays first, being the first mover or the Stackelberg leader, and the regions play second. In terms of this paper, that scenario means assuming that the regional governments have set up a central agency in charge of conducting interregional redistributive policy and of designing a framework for a subsequent action by the regional governments.

Thereafter we explore the opposite case where the centre is no longer in charge of taking initiatives but has to complete the actions of the regions in order to reach its redistributive objective. Finally we compare the outcome of the situations investigated in this section with that of the benchmark case of pure centralization, both in terms of overall welfare and of distribution of the researchers and the investment.

4.1 The central agency plays first

From equations (8) and (10) it turns out that

$$t_i - t_j = \frac{2M_i - 2M_j}{3} - \frac{2}{3}\tau_i$$

Substituting that expression for $t_i - t_j$ in those for α and m in (14), and deriving w.r.t. τ_i, we obtain

$$\tau_i^L = M_i - \frac{\mu}{2} - \tilde{\psi} \tag{31}$$

where a superscript L refers to the leadership of the central agency. Consequently,

$$\begin{aligned} t_i^L &= M_i + \frac{2}{3}M_j + \frac{\mu}{6} + \frac{\tilde{\psi}}{3} \\ t_j^L &= M_i + \frac{4}{3}M_j - \frac{\mu}{6} - \frac{\tilde{\psi}}{3} \end{aligned} \tag{32}$$

Comparing those equations with previous results immediately reveals that $\tau_i^L < \tau_i^S, \tau_i^C$ and $\tau_i^L < t_i^L, t_j^L$ illustrating the first mover advantage granted to the central agency. As a consequence, the subsidy allowed by the poorer region government is now larger than under simultaneous move though the subsidy offered by the richer region government is smaller. The effect on the distribution of the researchers and the investment becomes

$$\Delta m^L = \frac{1}{\mu}\left[M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right] \tag{33}$$

and

$$\Delta\alpha^L = \frac{2\varphi\left(1-\delta\right)}{\gamma\mu}\left[M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right] \tag{34}$$

so that welfare change is

$$\begin{aligned} \Delta W^L &= w\left(2\psi - 1\right)\Delta\alpha - um\left(t_i + \tau_i - t_j\right) - ut_j \\ &= 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\left[M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right] - \frac{u}{\mu}\left[M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right]^2 \\ &\quad -u\left[M_i + \frac{4}{3}M_j - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right] \end{aligned} \tag{35}$$

4.2 The regions are first movers

Suppose now that the regions move first. In that case, we obtain

$$\begin{aligned} t_i^R &= \frac{2}{3}\left(M_i + M_j\right) - \frac{\mu\left(1+m_0\right)}{3} + \frac{2}{3}\tilde{\psi} \\ t_j^R &= \frac{4}{3}\left(M_i + M_j\right) - \frac{\mu\left(2-m_0\right)}{3} - \frac{2}{3}\tilde{\psi} \end{aligned} \tag{36}$$

and

$$\tau_i^R = \frac{4M_i + M_j}{3} - \frac{\mu\left(1-2m_0\right)}{6} - \frac{5}{3}\tilde{\psi} \tag{37}$$

Interestingly, in this case, although the condition for the central agency to actually intervene remains a degree of commitment toward the poorer region larger than a given threshold, the first mover advantage of the poorer region now enables it to actually subsidize the researchers active in its territory only if the degree of commitment of the centre is smaller than a threshold.[11] In other words, when the commitment of the centre toward the poorer region is relatively high, the government of that region may use its first mover advantage to refrain from subsidizing researchers; it may entirely transfer the task of attracting researchers in its territory to the central agency. That substitution effect was already active in the $S-$ and $L-$settings but then it was sure that $t_i > \tau_i$.

It turns out that

$$\Delta m^R = \frac{1}{\mu}\left[\frac{2M_i - M_j}{3} + \frac{\mu\left(1-2m_0\right)}{6} - \frac{\tilde{\psi}}{3}\right] \tag{38}$$

$$\Delta \alpha^R = \frac{2\varphi\left(1-\delta\right)}{\gamma\mu}\left[\frac{2M_i - M_j}{3} + \frac{\mu\left(1-2m_0\right)}{6} - \frac{\tilde{\psi}}{3}\right] \tag{39}$$

and

$$\begin{aligned} \Delta W^R &= 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\left[\frac{2M_i - M_j}{3} + \frac{\mu\left(1-2m_0\right)}{6} - \frac{\tilde{\psi}}{3}\right] \\ &\quad -\frac{u}{\mu}\left[\frac{2M_i - M_j}{3} + \frac{\mu\left(1-2m_0\right)}{6} - \frac{\tilde{\psi}}{3}\right]^2 \\ &\quad -u\left[\frac{4}{3}\left(M_i + M_j\right) - \frac{\mu\left(2-m_0\right)}{3} - \frac{2}{3}\tilde{\psi}\right] \end{aligned} \tag{40}$$

[11] Although the condition for the centre to intervene is $\psi > \psi^R \equiv \frac{1}{2} + \frac{2+m_0}{20}\frac{\mu u \gamma}{w\varphi(1-\delta)}$ that for the government of region i is $\psi < \psi_i^R \equiv 2 - \frac{2+m_0}{4}\frac{\mu u \gamma}{w\varphi(1-\delta)}$. Notice that $t_j^R > 0$ requires $\psi > \psi_j^R \equiv -1 + \frac{4-m_0}{4}\frac{\mu u \gamma}{w\varphi(1-\delta)}$ but since $\psi_j^R < \psi^R$, that condition is always satisfied for the relevant range of values of the parameters.

4.3 Comparison again

We can now compare the last two situations with the benchmark case of pure centralization, first in terms of overall welfare gain, and then in terms of change in the distribution of the number of researchers and of the investment. We can state

Proposition 5 *It exists threshold values ψ^L and ψ^R of ψ, both larger than ψ^C and ψ^S, and with $\psi^L > \psi^R$, such that below each of those values, the central agency does not intervene in the sequential game in the corresponding setting - when either it plays first (L) or it plays second (R) - so that $\tau_i^L = 0$ or $\tau_i^R = 0$ respectively; above those values the central agency intervenes and the outcome under centralization is larger than in the sequential game, $\Delta W^C > \Delta W^L$ and $\Delta W^C > \Delta W^R$. Moreover, it exists a threshold value ψ^{LR} such that below that value $\Delta W^R > \Delta W^L$ and above that value $\Delta W^L > \Delta W^R$.*
Proof. *See Appendix A.5* ■

and

Proposition 6 *It exists a threshold value ψ_m^{CR} of ψ, with $\psi_m^{CR} \leq \psi^L$ such that the ranking provided by Table 4 appears, between Δm^C, Δm^L and Δm^R, and similarly between $\Delta\alpha^C$, $\Delta\alpha^L$ and $\Delta\alpha^R$.*
Proof. *See Appendix A.6* ■

Table 4 -Ranking of changes in m and α (cont'd)			
ψ	$\psi < \psi_m^{CR}$	$\in \left[\psi_m^{CR}, \psi^L\right]$	$\psi > \psi^L$
Δm	$\Delta m^R > \Delta m^C$	$\Delta m^C > \Delta m^R$	$\Delta m^C > \Delta m^R > \Delta m^L$

Note: $\Delta\alpha$ is a linear function of Δm

An observation arises from those two propositions. If centralization is not a feasible device and the commitment of the centre toward the poorer region is high, then, in terms of impact on the distribution of the researchers and of the investment, the $R-$setting is a better proxy for centralization than its L counterpart. However, this is not the case when comparison is conducted in terms of overall welfare change; then the $L-$setting may be a better proxy for centralization when the degree of commitment of the centre is high. That difference is due to the relatively higher cost of the $R-$scenario in that case. Indeed, in terms of the sole per capita subsidy we have that $\tau_i^R + t_i^R > \tau_i^L + t_i^L$ when

$$\psi > \frac{1}{2} + \frac{2 - m_0}{4} \frac{\mu u \gamma}{w\varphi\,(1-\delta)} > \psi^L$$

5 If the centre is Rawlsian, an extreme case

Let us now complete the analysis conducted so far by investigating the case where the centre is Rawlsian. Then $\psi = 1$, or $\tilde{\psi} = 0$ and the centre maximizes the welfare of the poorer region. In that framework we can first show that the size of the joint per capita subsidy to the researchers locating in region i is the smallest in case of centralization and the largest in case of simultaneous move. Decentralization and $L-$ and $R-$ settings are in between as it appears from the equations below,

$$\begin{aligned} t_i + \tau_i &= M_i\text{, centralization} \\ &= \frac{2}{3}\left(2M_i + M_j\right)\text{, decentralization} \\ &= 2M_i + \frac{2}{3}M_j - \frac{\mu}{3}\text{, central agency first} \\ &= 2M_i + M_j - \frac{\mu}{2}\text{, regions first} \\ &= 2M_i + M_j\text{, simultaneous move} \end{aligned} \tag{41}$$

based on equations (21), (32), (36) and (27) for t_i and on equations (17), (31), (37) and (27) for τ_i. Moreover one can use those equations to show that in this case, $t_i^R < t_i^S < t_i^L$ and $\tau_i^R > \tau_i^S > \tau_i^L$ illustrating the first mover advantage, especially for region i when the regions play first.

A similar comparison can be conducted for the Δm's, using equations (18), (28), (38), (33) and (22). It reveals that simultaneous move is the closest proxy for centralization followed by the $R-$ and $L-$ settings in that order while the position of decentralization is unclear, being parameter sensitive,

$$\begin{aligned} \mu\Delta m &= M_i\text{, centralization} \\ &= M_i - \frac{M_j}{2}\text{, simultaneous move} \\ &= M_i - \frac{M_i + M_j}{3} + \frac{\mu\left(1 - 2m_0\right)}{6}\text{, regions first} \\ &= M_i - \frac{2M_j}{3} - \frac{\mu}{6}\text{, central agency first} \\ &= M_i - \frac{M_i + 2M_j}{3}\text{, decentralization} \end{aligned} \tag{42}$$

It turns out, from a policy point of view, that, among the three designs where the two levels of power are active and when the commitment of the centre toward the poorer region is high, the simultaneous move is the best proxy for centralization in terms of benefit for the poorer region. However it is also the most costly. Then, deciding for a sequential design might reduce that cost, especially the cost per researcher locating in that region, but this at the expense of level of the approximation. Eventually the choice of the design will depend on the weight respectively given to costs and benefits.

6 Conclusions and avenues for further research

In this paper we have proposed an investigation of various institutional devices for the relations between a centre and two regional governments. We have conducted that investigation having in mind the European Union institutions and the interaction between the European Research Council and the regional policy. The European Regional Council provides high skill researchers with incentives to locate in universities in the territory of the European Union; regional policy aims at redistributing economic activity among the regions. In the present case, the instrument of that redistributive policy consists in subsidies to the researchers deciding to locate in the poorer region; that strategy is deemed to improve local human capital and thus to attract investment and generate employment. However interregional externalities may be at work and the regional authorities may also compete to attract researchers.

We have considered five settings. The first one provides us with a useful benchmark, assigning the exclusivity of the redistribution policy to a central agency, say the EU commission, whose action is in line with its degree of commitment toward the poorer region. That degree of commitment is exogenous and represented by a variable between .5 - no redistribution concern - and 1 - a Rawlsian centre. For any value of the degree of commitment such that the centre actually intervenes, that setting 1) provides the Union, or Federation, with the highest level of welfare, 2) provides the poorer region with the largest gain in terms of share of research activity and 3) does that at the least cost per researcher locating in that region for both the centre and the poorer region. At the other end, pure decentralization generates the least gain for the poorer region.

However, although pure centralization provides us with a benchmark device, it is not necessarily a feasible institutional design, especially in the EU. There is thus room for both a simultaneous and a sequential action of the two levels of authority. And in the latter case, it makes sense, especially when one has the EU in mind, to investigate what happens when the centre plays first and what also happens when the regions play first.

We show that, when the degree of commitment of the centre toward the poorer region is relatively high, the outcome of the simultaneous game is closer to that of centralization than the one of decentralization - Proposition 3 and Table 2 - and then the relative gain of the poorer region in terms of researchers, is also closer to the centralization outcome than in the decentralization setting - Proposition 4 and Table 3. From a comparison of those three settings, we can conclude that a simultaneous action by the two levels of authority is a better proxy for centralization than decentralization in a sufficiently advanced Union, or Federation, of countries. However the cost per researcher located in the poorer region is especially high under simultaneous move.

If there is room for a joint assignment of redistributive competencies to the two levels of government, one can usefully investigate what happens if they act sequentially. We start examining the case where the centre plays first. That case is in line with a federal design where the centre has the main authority, but it is less relevant for the EU where the centre is rather an agent of the national governments. Therefore we investigate the alternative setting, the regions playing first. That latter setting especially paves the way for the poorer region taking advantage of its status of (co-)first mover: when the commitment of the centre is high - take the case where $\psi = 1$ in Section 5 - the poorer region government reduces its subsidy, compared to the other two settings, transferring to the centre the task of attracting researchers in its territory. When the commitment of the centre is high, that behavior generates a gain for the poorer region in terms of researchers and investment, which is larger than when the centre plays first, but smaller however than under simultaneous move by the two levels of authority, and of course than under full centralization - see Proposition 6 and Table 4 as well as Section 5.

Those observations highlight the debate as to the institutional organization of the European Union. Since we cannot rule out an overlapping of competencies, designs of assignment of those competencies in such a way that the two levels of power act simultaneously or sequentially, either the centre or the regions playing first, have pros and cons and their respective properties depend on the degree of commitment of the centre toward the poorer region. In particular simultaneous move is better when the benefit of the poorer region in terms of researchers and investment is at stake and the commitment is high - see again the case investigated in Section 5. Instead, when budgetary effort per researcher is taken into account, the best interest of the poorer region, among the settings where the two levels of power are permitted to play, could be an institutional design where the redistributive commitment of the centre is high and the regions are first movers.

Coming back to the institutional organization of the European Union, that observation is important given the heterogeneity among the Member States in terms of development and in ability-to-pay.

Those observations also pave the way for further research. Some avenues should be investigated indeed. First, the hypothesis that the degree of commitment is exogenous, belonging to some interval, could be relaxed. Instead, the degree of commitment of the centre toward the poorer region could be the outcome of a negotiation between the regions. Second, the decision process as to the assignment of competencies to the centre, and as to the determination of its commitment to the poorer, or poorest, region as well, should be further investigated using the framework of coalition formation and assuming more than two regions. Alternatively we could remain in a two region setting and conduct the analysis from the point of view of the best interest of each player; rather than of the one of the Union. Finally we could reexamine some of settings, assuming incomplete information, especially of the centre. A reason for such an extension is that, in the EU, the centre has usually no mean to collect information directly.

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.

A Appendix A: Proof of Propositions

A.1 Proof of Proposition 1

A.1.1 (Threshold value ψ^C)

The central agency only intervenes if $\tau_i^C > 0$. That implies $M_i - \tilde{\psi} > 0$ or

$$\frac{w\varphi\left(1-\delta\right)}{u\gamma} - \frac{\mu m_0}{2} - 2w\left(1-\psi\right)\varphi\frac{1-\delta}{u\gamma} > 0$$

so that

$$\psi > \psi^C \equiv \frac{1}{2} + \frac{m_0}{4}\frac{\mu u\gamma}{w\varphi\left(1-\delta\right)} \tag{43}$$

a threshold value larger than 1/2.

Moreover, for ψ being smaller than unity, one needs

$$\frac{\mu m_0}{4}\frac{u\gamma}{w\varphi\left(1-\delta\right)} < \frac{1}{2}$$

which, given the highest possible value for m_0, requires

$$\frac{w\varphi\left(1-\delta\right)}{\mu u\gamma} > \frac{1}{4} \tag{44}$$

consistent with the condition issued for M_i and M_j to be positive - see equation (13).

A.1.2 ($\Delta W^C > \Delta W^D$)

Based on the comparison of equations (20) and (25), $\Delta W^C > \Delta W^D$ if

$$\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)^2 > 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\frac{2}{3}\left(M_i - M_j\right) - \frac{u}{\mu}\left[\frac{2}{3}\left(M_i - M_j\right)\right]^2 - u\frac{2}{3}\left(M_i + 2M_j\right)$$

which can be rewritten

$$\left[\left(M_i - \tilde{\psi}\right) - \frac{2}{3}\left(M_i - M_j\right)\right]^2 > -\mu\frac{2}{3}\left(M_i + 2M_j\right)$$

For that inequality to hold, a sufficient condition is that $M_i + 2M_j > 0$ which is precisely produced by the condition required for the subsidies being positive under decentralization.

A.2 Proof of Proposition 2

A.2.1 (Threshold value ψ^S)

The central agency only intervenes if $\tau_i^S > 0$. That implies

$$\frac{2M_i + M_j - 3\tilde{\psi}}{2} > 0$$

which in turn requires

$$3M_i - \frac{\mu\left(1-2m_0\right)}{2} - 3\tilde{\psi} > 0$$

or

$$3\frac{w\varphi\left(1-\delta\right)}{u\gamma} - \frac{\mu\left(1+m_0\right)}{2} - 6w\left(1-\psi\right)\varphi\frac{1-\delta}{u\gamma} > 0$$

involving

$$\psi > \psi^S \equiv \frac{1}{2} + \frac{1+m_0}{12}\frac{\mu u\gamma}{w\varphi\left(1-\delta\right)} \tag{45}$$

which is larger than ψ^C and smaller than one.

A.2.2 ($\Delta W^C > \Delta W^S$)

From the comparison of equations (20) and (30), $\Delta W^C > \Delta W^S$ requires

$$\begin{aligned}\frac{u}{\mu}\left(M_i-\tilde{\psi}\right)^2 \quad > \quad & 2\frac{u}{\mu}\left(M_i-\tilde{\psi}\right)\frac{2M_i-M_j-\tilde{\psi}}{2} - \frac{u}{\mu}\left[\frac{2M_i-M_j-\tilde{\psi}}{2}\right]^2 \\ & -u\frac{2M_i+3M_j-\tilde{\psi}}{2}\end{aligned}$$

or, after rearranging,

$$\left[\left(M_i-\tilde{\psi}\right) - \frac{2M_i-M_j-\tilde{\psi}}{2}\right]^2 > -\mu\frac{2M_i+3M_j-\tilde{\psi}}{2}$$

A sufficient condition for that inequality to hold is that

$$2M_i + 3M_j - \tilde{\psi} > 0$$

which is fulfilled since $M_i - \tilde{\psi} > 0$ due to the condition for τ_i^C being positive, and that M_i, $M_j > 0$ for t_i^D, $t_j^D > 0$.

A.3 Proof of Proposition 3

$\Delta W^C > \Delta W^D$ and $\Delta W^C > \Delta W^S$ have already been proved in Proposition 1 and 2 above. We still need to prove $\Delta W^S > \Delta W^D$.

A.3.1 $(\Delta W^S > \Delta W^D)$

Comparing equations (25) and (30) reveals that $\Delta W^S > \Delta W^D$ requires

$$\begin{aligned} & 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\frac{2M_i - M_j - \tilde{\psi}}{2} - \frac{u}{\mu}\left[\frac{2M_i - M_j - \tilde{\psi}}{2}\right]^2 \\ & -u\frac{2M_i + 3M_j - \tilde{\psi}}{2} \\ > \quad & 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\frac{2}{3}\left(M_i - M_j\right) - \frac{u}{\mu}\left[\frac{2}{3}\left(M_i - M_j\right)\right]^2 \\ & -u\frac{2}{3}\left(M_i + 2M_j\right) \end{aligned}$$

or, after rearranging

$$\frac{12M_i - 6M_j - 4\mu - 6\tilde{\psi}}{4}\frac{2M_i + M_j - 3\tilde{\psi}}{6} > \frac{8M_i - 8M_j}{3}\frac{2M_i + M_j - 3\tilde{\psi}}{6}$$

Since

$$\frac{2M_i + M_j - 3\tilde{\psi}}{6} > 0$$

we can divide both sides by that expression and the above inequality reduces to

$$\frac{12M_i - 6M_j - 4\mu - 6\tilde{\psi}}{4} > \frac{8M_i - 8M_j}{3}$$

which holds for

$$\psi > \psi^{SD} = \frac{1}{2} + \frac{19 - 5m_0}{36}\frac{\mu u \gamma}{w\varphi\left(1-\delta\right)}$$

A.3.2 $(\psi^{SD} > \psi^S)$

For $\psi^{SD} > \psi^S$, we need to have

$$\frac{1}{2} + \frac{19 - 5m_0}{36}\frac{\mu u \gamma}{w\varphi\left(1-\delta\right)} > \frac{1}{2} + \frac{1 + m_0}{12}\frac{\mu u \gamma}{w\varphi\left(1-\delta\right)} \tag{46}$$

or simply

$$m_0 < \frac{35}{13}$$

which holds since $0 \leq m_0 < 1/2$.

A.4 Proof of Proposition 4

By equations (18), (22) and (28) we have that inequalities $\Delta m^C > \Delta m^D$, $\Delta m^C > \Delta m^S$ and $\Delta m^S > \Delta m^D$ respectively require

$$\frac{M_i + 2M_j}{3} > \tilde{\psi};\ M_j > \tilde{\psi} \text{ and } 2M_i + M_j > 3\tilde{\psi}$$

One can easily show that the first inequality, $\Delta m^C > \Delta m^D$, holds if

$$\psi > \psi_m^{CD} \equiv \frac{1}{2} + \frac{2 - m_0}{12} \frac{\mu u \gamma}{w\phi (1 - \delta)} \tag{47}$$

and we observe that $\psi_m^{CD} > \psi^C$. The second inequality, $\Delta m^C > \Delta m^S$, requires that

$$\psi > \psi_m^{CS} \equiv \frac{1}{2} + \frac{1 - m_0}{4} \frac{\mu u \gamma}{w\phi (1 - \delta)} \tag{48}$$

and $\psi_m^{CS} > \psi_m^{CD}$. Finally, the last inequality, $\Delta m^S > \Delta m^D$, involves

$$\psi > \psi_m^{SD} \equiv \frac{1}{2} + \frac{1 + m_0}{12} \frac{\mu u \gamma}{w\phi (1 - \delta)} \tag{49}$$

and one can note that $\psi^C < \psi_m^{SD} < \psi_m^{CD}$.

$\Delta\alpha$ is a linear function of Δm so that what applies to the latter applies to the former.

A.5 Proof of Proposition 5

A.5.1 (L, $\Delta W^C > \Delta W^L$)

The central agency intervenes in the sequential game when it plays first if $\tau_i^L > 0$, which implies

$$M_i - \frac{\mu}{2} - \tilde{\psi} > 0$$

and then

$$\psi > \psi^L \equiv \frac{1}{2} + \frac{1 + m_0}{4} \frac{\mu u \gamma}{w\varphi (1 - \delta)} > \psi^S > \psi^C \tag{50}$$

For those values of ψ, $\Delta W^C > \Delta W^L$. Indeed, by equations (20) and (35), $\Delta W^C - \Delta W^L > 0$ requires

$$\left(M_i - \tilde{\psi}\right)^2 - 2\left(M_i - \tilde{\psi}\right)\left[M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right] + \left[M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right]^2$$
$$+\mu\left[M_i + \frac{4}{3}M_j - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right] > 0$$

and

$$\left[M_i - \tilde{\psi} - M_i + \frac{2M_j}{3} + \frac{\mu}{6} + \frac{\tilde{\psi}}{3}\right]^2$$
$$> \quad -\mu\left[M_i + \frac{4}{3}M_j - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}\right]$$

which holds if the right hand side of the inequality is negative. Since the term between brackets in the right hand side of that inequality actually is $t_j^L > \tau_i^L$ which is never negative, the inequality actually holds.

A.5.2 (R, $\Delta W^C > \Delta W^R$)

The central agency intervenes in the sequential game when it plays second if $\tau_i^R > 0$, which implies

$$\frac{4M_i + M_j}{3} - \frac{\mu(1 - 2m_0)}{6} - \frac{5}{3}\tilde{\psi} > 0$$

and then

$$\psi > \psi^R \equiv \frac{1}{2} + \frac{2 + m_0}{20}\frac{\mu u \gamma}{w\varphi(1 - \delta)} > \psi^S > \psi^C \tag{51}$$

For those values of ψ, $\Delta W^C > \Delta W^R$. Indeed, by equations (20) and (40), $\Delta W^C - \Delta W^R > 0$ requires

$$\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)^2 - 2\frac{u}{\mu}\left(M_i - \tilde{\psi}\right)\left[\frac{2M_i - M_j}{3} + \frac{\mu(1 - 2m_0)}{6} - \frac{\tilde{\psi}}{3}\right]$$
$$+\frac{u}{\mu}\left[\frac{2M_i - M_j}{3} + \frac{\mu(1 - 2m_0)}{6} - \frac{\tilde{\psi}}{3}\right]^2$$
$$+u\left[\frac{4}{3}(M_i + M_j) - \frac{\mu(2 - m_0)}{3} - \frac{2}{3}\tilde{\psi}\right] > 0$$

and

$$\left[M_i - \tilde{\psi} - \frac{2M_i - M_j}{3} - \frac{\mu(1 - 2m_0)}{6} + \frac{\tilde{\psi}}{3}\right]^2$$
$$> \quad -\mu\left[\frac{4}{3}(M_i + M_j) - \frac{\mu(2 - m_0)}{3} - \frac{2}{3}\tilde{\psi}\right]$$

which holds if the right hand side of the inequality is negative. Again, the term between brackets on the right hand side of the inequality is t_j^R which is non-negative; therefore the inequality holds.

Moreover we can easily show that $\psi^L > \psi^R > \psi^S$

A.5.3 $(\Delta W^L > \Delta W^R)$

Finally we turn to the comparison between ΔW^L and ΔW^R using equations (35) and (40); $\Delta W^L - \Delta W^R > 0$ implies

$$\begin{aligned}&2\frac{u}{\mu}\left(M_i-\tilde{\psi}\right)\left[M_i-\frac{2M_j}{3}-\frac{\mu}{6}-\frac{\tilde{\psi}}{3}\right]\\&-2\frac{u}{\mu}\left(M_i-\tilde{\psi}\right)\left[\frac{2M_i-M_j}{3}+\frac{\mu\left(1-2m_0\right)}{6}-\frac{\tilde{\psi}}{3}\right]\\&-\frac{u}{\mu}\left[M_i-\frac{2M_j}{3}-\frac{\mu}{6}-\frac{\tilde{\psi}}{3}\right]^2+\frac{u}{\mu}\left[\frac{2M_i-M_j}{3}+\frac{\mu\left(1-2m_0\right)}{6}-\frac{\tilde{\psi}}{3}\right]^2\\&-u\left[M_i+\frac{4}{3}M_j-\frac{\mu}{6}-\frac{\tilde{\psi}}{3}\right]+u\left[\frac{4}{3}\left(M_i+M_j\right)-\frac{\mu\left(2-m_0\right)}{3}-\frac{2}{3}\tilde{\psi}\right]>0\end{aligned}$$

which requires

$$\psi > \psi^{LR} \equiv \frac{1}{2} + \frac{15-2m_0}{8}\frac{\mu u\gamma}{w\varphi\left(1-\delta\right)} > \psi^{SD} > \psi^L > \psi^R > \psi^S \tag{52}$$

A.6 Proof of Proposition 6

By equations (18), (33) and (38) we have that inequalities $\Delta m^C > \Delta m^L$, $\Delta m^C > \Delta m^R$ and $\Delta m^R > \Delta m^L$ respectively require

$$M_i - \tilde{\psi} > M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}$$

$$M_i - \tilde{\psi} > \frac{2M_i - M_j}{3} + \frac{\mu\left(1-2m_0\right)}{6} - \frac{\tilde{\psi}}{3}$$

and

$$\frac{2M_i - M_j}{3} + \frac{\mu\left(1-2m_0\right)}{6} - \frac{\tilde{\psi}}{3} > M_i - \frac{2M_j}{3} - \frac{\mu}{6} - \frac{\tilde{\psi}}{3}$$

The first inequality involves

$$\psi > \psi_m^{CL} \equiv \frac{1}{2} + \frac{1-2m_0}{8}\frac{\mu u\gamma}{w\varphi\left(1-\delta\right)} \tag{53}$$

However, $\psi_m^{CL} < \psi^L$ so that the inequality always holds in the relevant range of values for ψ. Therefore $\Delta m^C > \Delta m^L$ always. The second inequality, $\Delta m^C > \Delta m^R$, holds if

$$\psi > \psi_m^{CR} \equiv \frac{1}{2} + \frac{1-m_0}{4}\frac{\mu u\gamma}{w\varphi\left(1-\delta\right)} \tag{54}$$

That latter threshold, ψ_m^{CR}, is smaller than ψ^L but larger than ψ^R. Finally, the last inequality, $\Delta m^R > \Delta m^L$ always holds too.